Bulletin 368
January 1955

Diseases of Wheat in Kansas

AGRICULTURAL EXPERIMENT STATION
Kansas State College
of Agriculture and Applied Science
Manhattan

FEB 1956

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Cover Picture—The striking effect of a disease upon yield. Wheat plants were infected with leaf rust at various stages and carried to maturity, each sample representing the yield of 30 plants. Plants infected at (1) two-leaf stage, (2) jointing, (3) booting, (4) flowering, (5) Plants rust free throughout life.

Diseases of Wheat in Kansas[1]

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INTRODUCTION

All plants are subjected at times to attack by numerous parasites. This is especially true of the wheat plant. Evidence of disease is to be seen as stunting of the plants, spots on leaves and stems, destruction of the grain, rotting of roots and crown, and mildew, to mention only a few.

Most of the diseases of wheat are caused by fungus parasites. Fungi are true plants but, unlike ordinary plants, they lack the green pigment, chlorophyll, which is responsible for the manufacture of food. As a result they depend upon food that the green plant already has prepared. When fungi attack a living plant, or animal, and obtain food from it, we call them parasites. Because the fungus plant is microscopic, its parts are difficult to see. They possess a threadlike structure that serves at once as roots, a means of spreading from one part of the plant to another, and branches on which spores are produced.

These spores (often incorrectly called seeds) are small bodies produced by the millions. They are so light that they are readily carried by the wind to the next field or to the next state where they start further infections. If moisture and temperature conditions are favorable, the spores germinate, producing threads which enter the plant. In a short time millions of new spores are produced, ready to start the cycle over again. Rusts, smuts, mildew and take-all are excellent examples of fungi that successfully live as parasites on wheat. Some diseases, like crown or foot rot, are soil borne rather than air borne, and spread slowly through the soil.

Bacterial diseases are relatively uncommon on wheat but a few sometimes cause serious losses. Like most fungi they thrive in wet weather. In a wet year such bacterial diseases as black chaff may be abundant.

Viruses and virus diseases are not well understood. It is not yet known how they should be classified. They are not fungi, as they lack spores, nor are they bacteria, since they do not form typical cells. They exist only as protein particles within living cells, and are so small that they can be

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seen only with an electron microscope with a magnification of approximately 20,000. It is certain, however, that they are parasites, and important ones, as the losses from wheat mosaic in 1949 (Fig. 1) indicate. Some viruses are carried by insects. It has been discovered recently that one of the two virus diseases of wheat in Kansas, the wheat streak mosaic, is carried by a tiny mite. Virus diseases appear to be on the increase and pose many problems for the plant pathologist and plant breeder.

Much progress has been made in the last 25 years in gaining knowledge of these parasites and in methods to control them. As a result, some diseases, such as flag smut, have completely disappeared. At the same time new diseases, such as mosaics, are constantly appearing, and even new strains of old diseases like leaf and stem rust suddenly develop to present a constant threat to the nation's wheat crop.

Each year for 25 years the Department of Botany and Plant Pathology at Kansas State College has been conducting annual surveys to determine the kind of diseases present in Kansas wheat fields, as well as the prevalence and intensity of attack of the epidemic diseases. From this information it has been possible to determine losses due to diseases. It should be remembered that the wheat plant is subject to attack at any stage of growth. As a result the yield may be reduced in amounts varying from a trace to total loss. This reduces the farmer's income by reducing the yield and lowering the quality and market value of the grain. The average annual yield of hard winter wheat in Kansas from 1944 to 1953 was 204,735,800 bushels, and the average annual loss from stem rust over this period was 1,402,677 bushels. During an epidemic year losses may be extremely high: in 1944 stem rust alone caused a loss of 7,508,000 bushels in Kansas, and in 1949 leaf rust reduced the crop an estimated 16,420,800 bushels.

To illustrate the effect of plant diseases upon yield, a tabulation has been made of the diseases of wheat as they occurred in Kansas in 1949 (Fig. 1). The total combined losses represent a figure of considerable importance. Whereas 1949 was a year of unusually heavy losses from disease, the 1952 crop was produced under such favorable circumstances that diseases were held to a minimum and yields reached an all time high. No two years are alike and the amount of disease depends upon many factors, the most important of which are the presence or absence of the parasite and conditions during the growing season.

Thus far it has not been possible to produce a wheat completely resistant to all diseases. Nevertheless, considerable progress has been made in producing varieties that re-

sist one or more of the major diseases. The resistance and susceptibility of some of the important varieties of wheat to the seven major diseases are given in Table 1.

Table 1. Reaction of some hard red winter wheat varieties to major wheat diseases in Kansas.*

Variety	Leaf rust	Stem rust	Streak mosaic	Soil mosaic	Loose smut	Stinking smut	Septoria
Pawnee	S	S	S	MS	HR	MR	HS
Wichita	HS	S	S	SR	S	S	S
Comanche	S	MS	S	R	S	HR	S
Kiowa	HS	HS	SR	S	HS	HR	S
Triumph	HS	HS	SR	S	R	S	S
RedChief	S	S	S	S	HS	HS	SR
BlueJacket	S	S	SR	S	HS	S	S
Ponca	HR	S	S	S	R	S	S
Tenmarq	S	S	S	—	S	S	S
Concho	HR	HS	S	R	S	HR	S
Cheyenne	HS	HS	—	S	S	S	S

*HR=highly resistant; R=resistant; MR=moderately resistant; SR=slightly resistant; MS=moderately susceptible; S=susceptible; HS=highly susceptible.

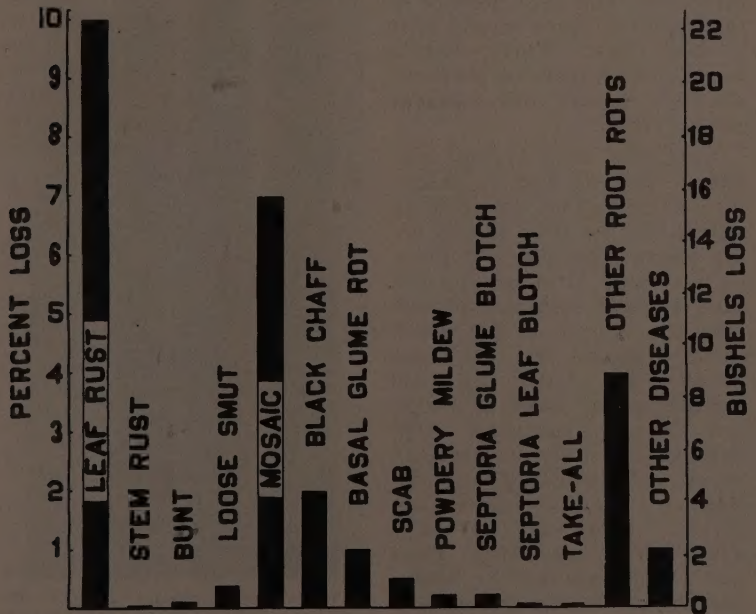

Fig. 1.—Wheat diseases in Kansas in 1949 showing percent loss (left) and millions of bushels loss (right).

LEAF RUST

Leaf rust is one of the most destructive diseases of wheat in Kansas. It is estimated that this disease alone reduced the yield of wheat more than 5,431,000 bushels a year from 1938 to 1952, inclusive. **Its damage usually is underestimated because it never totally destroys a Kansas crop and seldom causes severe shriveling of the grain. However, it has been proved that leaf rust reduces the number of kernels per head and the size of the kernels** (Cover Photo). Leaf rust is present in nearly all sections of the state every year and is abundant in some parts nearly every year. In general, infections tend to be heavier in the eastern, more humid half of the state. Warm, humid weather with dews or frequent showers favors development of leaf rust.

Leaf rust is a typical airborne disease and is maintained throughout the growing season by the tiny spores being blown from place to place by the wind. Although the disease is sometimes able to survive the winter as far north as the Dakotas, fall infections usually are killed by cold weather as far south as northern Texas. Usually it overwinters on actively growing wheat in southern Texas and Mexico. Then its spores are carried northward by the winds during the spring. Thus leaf rust gradually moves northward during the spring months as temperature and moisture conditions become favorable for its development. The process is reversed in the fall, spores being blown southward where they cause infections on fall-sown wheat. The organism thus survives the winter in the red spore stage.

The most conspicuous stage of the disease, and the one which reduces yields, is the active red-spore stage on the leaves. In this stage the or-

Fig. 2.—Pustules of leaf rust on the leaves of adult wheat plants, showing small size and noncoalescent nature.

ganism feeds on materials that would normally be used in grain production by the wheat plant. During this period large numbers of spots or pustules are produced, principally on the leaves and leaf sheaths (Fig. 2). Infections occasionally develop on the pedicels (stalks) of the head, on the glumes, and on the awns (beards), but only under unusual conditions such as those occurring in low, wet locations or lodged spots in the field.

The leaf rust pustules are small, round (or nearly so), orange-red to brown in color. The most conspicuous ones are on the leaves, hence the name "leaf rust." The pustules are more numerous on the upper than the lower surface of the leaf although there frequently are a considerable number on both sides. Many on the upper surface do not penetrate the leaf and produce a similar pustule on the opposite side, as they usually do in the case of stem rust. Since leaf rust pustules are relatively small, they do not raise large sections of the outer plant tissues nor rupture the leaf surface, exposing jagged fragments, as is characteristic of stem rust.

The mature, or black-spore stage of leaf rust appears as the wheat plants near maturity. The pustules are small and inconspicuous and are covered by the surface leaf tissues, giving them a glossy black appearance. **The black stage does no damage to the crop.**

Like all of the cereal rusts, leaf rust of wheat is composed of many parasitic races or strains. These cannot be distinguished by ordinary examination or even by microscopic differences. They can be separated only by the reaction of certain wheat varieties to them. A variety may be highly resistant to one race and completely susceptible to another. Thirty-three such races have been found in Kansas, but only five or six are abundant and widely distributed. These races must be considered in breeding leaf rust resistant varieties.

The best way now known to control leaf rust is to produce resistant varieties. Unfortunately most of the older standard varieties of hard red winter wheat were susceptible, so it has been necessary to resort to selection and hybridization to produce resistance. There is considerable resistance in some North American varieties of soft red winter and hard red spring wheat. There also is much leaf rust resistance among wheats of foreign origin, particularly those of Australia, Argentina, Brazil, and Peru. All of these sources of resistance are represented in the present program of the Kansas Agricultural Experiment Station in breeding hard red winter varieties resistant to leaf rust. The varieties Ponca and Concho are the only hard red winter wheats now commercially grown that have high resistance to leaf rust in the field (Table 1). Some varieties like Triumph and Wichita, although suscep-

tible, often escape infection through early maturity.

Some sprays and dusts have been shown to be effective in controlling rusts, but none is considered practical in Kansas. Fine dusting sulfur properly applied has given good rust control, but the rate of application is high and the dust must be replaced after each rain. The dust must be applied by airplanes and the explosion and fire hazard to pilots and planes are deterring factors.

STEM RUST

Stem rust is potentially one of the most dangerous diseases of wheat in Kansas. Although stem rust may be found in Kansas practically every year, heavy losses occur only in certain years. In the last 10 years stem rust has caused losses in only two years: 1953 with 2,202,974 bushels loss and 1954 when the loss was estimated at 4,363,650 bushels for the state. As a rule stem rust is most damaging in moist regions and during moist seasons in areas like Kansas that normally have a low average rainfall.

Stem rust, like all rust diseases, is a fungus parasite. It can usually be distinguished without much difficulty from other wheat diseases, although in its early stages, it may resemble leaf rust. Stem rust is seen in the fields as brick red elongated pustules on the stems, leaves, sheaths, glumes, and awns; in fact, it may occur on any green part of the plant. By contrast leaf rust infections are round, orange red to brown in color and are found primarily on the leaves. Stem rust pustules usually are much larger than leaf rust pustules and often coalesce. The red spore stage of both rusts tends to disappear with maturity of the wheat and be replaced by a black spore stage. Any stem rust present on the stems and necks can be detected readily as a rough surface by running the fingers over the stems below the heads.

Stem rust usually appears in Kansas late in May or early in June, depending on weather conditions. These early rust infections are caused by red spores blown into Kansas from wheat fields in Mexico, Texas, and Oklahoma. Usually any rust that is present in Kansas in the fall is killed by low winter temperatures, but in extremely mild winters stem rust has been known to live over on wheat or certain grasses and become established early in the spring.

For infection to occur, the overwintering or blown-in red spores must come in contact with some form of free water on the surface of the plant and germinate. This moisture may be in the form of rain, dew, or water given off from the plants themselves. From the time these red spores infect a wheat plant, approximately 10 days are required for a new rust pustule to appear. These new pustules in turn produce millions of red spores that are picked up by the wind and carried to adjoining plants, in the next wheat field, or into

the next state where each is capable of causing a new infection. If moisture is present, new infections take place and a new crop of rust pustules appears, each with its millions of spores. Because of this repeated infection cycle of the red spore stage, the date of the first appearance of stem rust is critical. The earlier the rust appears the more time available for the rust to multiply. This is especially important, since each rust pustule continues to discharge spores into the air as long as the stem is green.

The red spore stage is responsible for the damage. The rust fungus utilizes nutrients and water that normally would be used in growth and development of the wheat kernel. Un-

Fig. 3.—Grain and straw from a stem rust resistant variety and a stem rust susceptible variety of winter wheat grown in adjacent rows. Note severe shriveling of grain from the stem rust infected row.

der extreme conditions, especially when infections are heavy on the stems just below the heads, many heads will contain no grain. With moderate infection the heads will contain only small shriveled kernels (Fig. 3). Stem rust also weakens the stems, causing lodging and loss of grain. Heavily rusted fields do not

Fig. 4.—The black-spore stage of stem rust on the stems of wheat showing the elongate, coalescent pustules and the ruptured plant epidermis.

ripen normally. They are greenish gray, and ripening is sometimes delayed several days.

The black spore stage (Fig. 4) does not injure the wheat. These black spores germinate the following spring and produce small spores that infect the common barberry bush, if it is nearby and conditions are favorable. The cluster cup stage of the rust is formed on the common barberry where new types or races of stem rust may be produced. The rust then spreads from the barberry to adjoining wheat fields. The barberry stage of stem rust is not a factor in the spread of rust in Kansas; however, this stage of the rust is important to the north and east of Kansas. The danger of the barberry in initiating local infections and serving as a source of new races of stem rust is recognized and the common barberry has been declared a noxious weed in Kansas. It also is illegal to ship the plant into Kansas. In recent years all but a few of the known common barberry bushes in the state have been removed. All of the rust susceptible barberries should be destroyed.

Stem rust of wheat is composed of many physiologic races. More than 200 are known but only a few are prevalent in the hard red winter wheat area. For many years prior to 1950 race 56 was the most abundant race in Kansas. Races 17 and 38 also were present but only in small amounts. The program of breeding stem rust resistant wheats for Kansas was built largely around resistance to these three races.

In 1950 there was a sharp change in the physiologic race flora of the entire Mississippi Valley when a new race, 15B, suddenly appeared and became

the most abundant and widely distributed race. This virulent race attacks all commercial varieties of wheat in the United States. The sudden appearance in recent years of new and virulent races, such as 15B, has caused a revision in the program of breeding for stem rust resistance. New sources of resistance are being sought and hybridizing programs are being revised to incorporate them with hard winter wheat.

Stem rust is most effectively controlled by resistant varieties. At the present time none of the commercial varieties of winter wheat grown in Kansas is highly resistant to stem rust, especially to race 15B (Table 1). Comanche and Pawnee wheats have a degree of tolerance under field conditions. Some early varieties, such as Triumph and Wichita, often are able to escape heavy rust infection because their early maturity shortens the critical infection period.

Stem rust may be successfully controlled by spraying or dusting, although the method is not economically practical yet. Sulfur dust and other new fungicides will reduce rust infection. Considerable research is being done on this method of control.

VIRUS DISEASES OF WHEAT—THE MOSAICS

There are now (1954) at least two economically important wheat mosaic diseases in Kansas, soil-borne mosaic and streak mosaic. They infect wheat, some other crop plants in the grass family, and certain wild grasses. They are distinctly different diseases. They are called "mosaics" because the leaves of diseased plants often have yellowish-green mottling, streaking and striping rather than the uniform green of healthy plants.

Soil-borne mosaic. This virus disease is confined for the most part to the eastern third of the state. It has been found in widely scattered fields for several years but the first widespread known damage occurred in 1952. Many fields were badly diseased with losses estimated at $1,500,000 with yield reductions in individual fields of 5 to 13 percent. The disease was even more widespread and severe in 1954. Losses were as high as 75 percent in some diseased spots, the average being approximately 15 to 25 percent. The loss for 1954 was estimated at $3,000,000.

Badly diseased spots in a field appear as bronze-yellowish areas in early spring. The diseased yellow-green plants in these spots gradually turn green with the beginning of warm weather. However, individual plants suffering from this disease may still have leaves mottled and streaked with lighter green to greenish-yellow areas (Fig. 5). Later in the season in the diseased spots plants may be stunted somewhat, varying with the season. Often there will be fewer and shorter heads on the diseased plants. The grain in

Fig. 5.—Leaves illustrating symptoms of soil-borne mosaic on Pawnee wheat. Healthy leaf at far left, younger diseased leaves grouped on the left and older diseased leaves on the right.

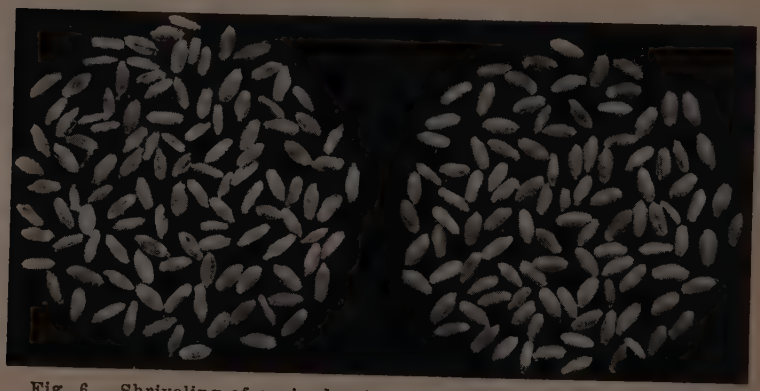

Fig. 6.—Shriveling of grain due to soil-borne mosaic in 1954 in Ponca wheat (left). Grain on right from healthy plants from the same field.

infected plants may be severely shriveled (Fig. 6).

How this virus gets into the soil initially is not known, nor are any insect carriers or other vectors known. It is not carried in the seed. Once in a certain soil, however, it remains for many years, causing infection year after year. The virus is capable of moving slowly with any movement of infested soil. Also, the roots of plants growing in healthy soil may grow out into infested soil and pick up the disease and in this way gradually move the virus across a field.

A growing period with a mean temperature of 60° F or less appears to be necessary before Kansas wheat varieties are damaged appreciably by this disease. These long cool growing periods in both fall and spring are rather rare in Kansas. Hence, this virus, even though present in the soil, has not been a significant factor in yield reduction every year, nor is it expected to be.

Since the virus persists in the soil for many years, crop rotation is of little, if any, value in control. Resistant varieties appear to offer the most hope. Both Comanche and Concho are resistant (Table 1) and selections from several other acceptable varieties are showing great promise. Others probably will be discovered within the next few years.

Streak mosaic. This virus disease of wheat is widespread in Kansas. It has been particularly severe in the western half of the state and has been found in all areas except the southeast. It has been present for many years, certainly since 1929, and probably long before that. The damages caused by it undoubtedly were attributed to other presumed causes in earlier years, and much confusion still exists. The first known widespread and severe outbreak occurred in 1949. Losses that year were estimated at $30,000,000 in Kansas. Many fields in the western counties were abandoned. Since 1949, losses have varied from none in 1952 to $13,000,000 in 1951 and approximately the same in 1954. Yield reductions in individual infected fields vary but seldom are under 20 percent and often are 50 to 70 percent or more.

The most important known method of spread is by a tiny, four-legged, cigar-shaped mite called the wheat curl mite.[4] This creature is so tiny that it must be magnified about 10 times even to be seen, and about 30 to 40 times to be studied. It is a very efficient carrier of the disease and is widespread in Kansas.

The virus is neither seed nor soil borne. It is not transmitted by blowing soil, machinery, grazing of livestock, or root to root contacts of diseased and healthy plants. It is carried to some extent from diseased to healthy plants when the leaves interlace and whip back and forth during strong winds. Leaves are injured by this severe lashing

4. For photographs and information see Bul. 367, Insects That Attack Wheat in Kansas.

and some of the sap from injured diseased leaves may then contact injured areas on healthy leaves, thereby gaining entrance into healthy plants.

The virus overwinters in living diseased wheat plants and in some perennial grasses. The mites carry the virus in the spring from diseased wheat to various susceptible grasses and in the summer to any early volunteer wheat. In the fall the virus is carried to early fall planted wheat. However, with the death of the plant or at harvest, the virus is very rapidly destroyed. No active virus has been found in stubble or in dead plant remains of diseased plants.

Other crop plants such as oats, barley, rye, and corn also may get this disease but they are not damaged much by it. Some corn varieties, sorghum, and several of the major pasture grasses of the state do not take the disease at all. It is reasonably certain that wheat is the only Kansas crop plant severely damaged by it. So far it has not been possible to infect any of the weedy plants other than grasses.

Wheat streak mosaic is more severe during warm or hot weather. Diseased plants tend to be hurt more by drouth. They seem also to be attacked more severely than healthy plants by various root and crown rotting organisms that live in the soil. Severely diseased mosaic plants have a tendency to look drouthy as they mature, even when there has been ample rainfall. Cool weather with adequate moisture minimizes the damage, but losses in infected fields have seldom been less than 20 percent, even in the more tolerant varieties.

For winter wheat plants to be damaged severely, infection must occur in the fall when plants are young. The earlier the fall infection, the more severe the loss will be. By spring the plants have developed a tolerance to the disease; consequently, although spring infection of winter wheat plants is common, the loss in yield is slight.

Leaf symptoms are occasion-

Fig. 7.—Illustrating stunting effect of wheat streak mosaic on immature greenhouse-grown plants of the variety Westar. Plant at left is diseased, showing extreme stunting, shorter heads, mottled and yellowed leaves. In healthy plant at right some heads have not emerged from the boot.

Fig. 8.—Mottled and streaked leaves characteristic of streak mosaic on Pawnee wheat. Healthy leaf is at far right. Younger diseased leaves are shown on the right half and older leaves to the left.

ally seen during a long warm fall, but usually the characteristic yellowing, mottling, and stunting are not seen until the arrival of warm spring weather. Then, if warm weather persists, diseased plants become yellow and stunted (Fig. 7) (varying considerably with the variety) and the yellowish streaking and mottling of the leaves (Fig. 8) may be seen. The mottling and yellowing symptoms gradually disappear as the plants mature, but the stunting persists and the yellow leaves tend to turn brownish and die. Often diseased fields have two distinct levels of maturing heads (Fig. 9). The tall heads may be either plants that have escaped infection or sometimes are individual tillers of diseased plants which for some reason have not been stunted.

The best control method known so far is to plant at the latest recommended date for a given area. This helps the young plants escape early fall infection by the mite. In addition, destruction of all early volunteer wheat and possibly also weed grasses helps to eliminate an enormous number of plants in which the virus may persist during the

summer. No resistant varieties are available so far. Two acceptable standard varieties, Triumph and Kiowa, have some tolerance (Table 1), but if the disease situation is severe, these too can be badly damaged. An extensive search is now being made for resistance. It is hoped that more resistant varieties may be discovered.

Fig. 9.—Extremely stunted plants caused by streak mosaic in Pawnee variety. Block of plants under left arrow are healthy; those under right arrow are diseased. Note the two-step effect.

LOOSE SMUT

Loose smut is now the major smut disease of wheat in Kansas. During the last 10 years the average loss due to this disease was 0.7 percent or 1,700,000 bushels of wheat annually.

Loose smut is generally distributed over the state. It is favored by high humidity during the few days following heading when the wheat is in blossom; consequently, it is more prevalent in susceptible varieties in eastern than in western Kansas.

Generally loose smut is not observed until after the wheat has headed. The black smut mass not only replaces the kernels but also the glumes and the brownish-black heads are quite conspicuous (Fig. 10). The spores are carried away gradually by the wind or washed off by rain, and after about 10 days only the bare central stem of the head remains (Fig. 10).

The healthy heads of wheat are infected during the blossoming period and the smut grows into the germs of the kernels. Therefore, no chemical applied to the surface of the seed is effective in the control of this disease. When the infected seed is planted in the fall, the dormant smut within the germ becomes active and grows up inside the plant. When the wheat plant forms heads the following spring, loose smut heads appear instead of healthy heads. The only practical control of loose smut is to grow resistant varieties. In Kansas Pawnee is highly resistant, while Triumph and Ponca have satisfactory resistance (Table 1). These varieties were grown on 40 percent of the acreage of wheat in Kansas in 1954.

Loose smut may be controlled also by treating seed with hot water. This treatment, however, is expensive, re-

quires special equipment and accurate control of the temperature of the water; consequently, it is not generally recommended. Each year wheat seed is treated at the Kansas

Fig. 10.—Loose smut. Left, healthy head; center, smutted head; right, smutted head after spores have been blown or washed away.

State College Branch Experiment Station at Hays. Foundation seed produced from this crop is relatively free from loose smut and thus losses from smut in the variety treated are not so high as they otherwise would be.

STINKING SMUT

Stinking smut, also called bunt and covered smut, has been, and potentially still is, a major disease of wheat. During the 10-year period from 1921 to 1930, inclusive, the average annual loss of wheat due to this disease in Kansas was 3.7 percent, or 5 million bushels. An effective seed treatment program and development of resistant varieties have reduced losses due to this disease markedly. During the last 10 years, the average loss dropped to 0.14 percent or 300,000 bushels.

The disease is generally distributed and prevalent in susceptible varieties of wheat in Kansas. Stinking smut causes loss in yield and in addition reduces the quality of the grain. The spores of the smut must be removed by washing before the wheat is milled; consequently, the grain is graded smutty and demands a lower price.

Stinking smut is generally not apparent until 10 to 20 days after heading. The infected plants are stunted, being about three-fourths as tall as the healthy plants. The heads have a characteristic bluish-green color, are not so long, and in general have a laxer, ragged, and more open appearance (Fig. 11). The smut balls replace the kernels of wheat and are first grayish-green but later change to brown as the grain ripens (Fig. 11). These are filled with a brownish-

Fig. 11.—Stinking smut. Left, healthy head, kernels, and kernels cut transversely; right, smutted head, smutted kernels, and smutted kernels cut transversely.

black mass of spores with a distinctly fishy odor, readily detected in the field and in the grain after it is harvested.

During harvesting most of the smut balls are broken and the good seed is covered with the spores. Seed infected heavily may be detected by its fishy odor, by the presence of spores on the surface, in the brush of the seed, and by the presence of unbroken smut balls.

When smutty seed is planted

in the fall, the smut spores germinate and infect the young wheat seedlings before they emerge. The smut then grows within the plant its full length and the following spring replaces the kernels of wheat with smut balls.

Stinking smut may be controlled by treating the seed with a recommended fungicide before planting. The mercury fungicides Panogen and Ceresan M and the nonmercury fungicide Vancide 51 are recommended for the treatment.[5] Other promising fungicides are being tested.

Stinking smut also may be controlled by growing resistant varieties. In Kansas Comanche and Kiowa are highly resistant while Pawnee has satisfactory resistance to this disease. These varieties were grown on 49 percent of the Kansas acreage of wheat during 1954.

Another practical method that helps reduce losses from this disease is to plant wheat as soon as possible after the Hessian fly free date while soil temperatures are still generally high. Cool soil temperatures are highly favorable for smut infection.

SPECKLED LEAF BLOTCH

Speckled leaf blotch, also called Septoria leaf blotch and Septoria leaf blight of wheat may be found wherever wheat is grown in Kansas. However, the severity of this disease varies greatly between regions and from season to season. Leaf blotch thrives best in portions of the state where rainfall is the greatest and is accordingly most destructive when there is a long wet season. The greatest consistent losses are in the south-central and southeast portions of the state. During wet seasons the extent of leaf damage may be quite high throughout the eastern half of the state.

This disease causes spots or blotches on the leaves which are frequently indefinite in color, size, and margin. Generally the tissue around the spot loses its green, becoming straw colored or brown. As the leaves bleach and plants mature, the spots become thickly covered with small black dots about the size of pin points (Fig. 12). These are the fruiting bodies of the parasitic fungus from which the disease is spread if sufficient moisture is on the leaf surface. The presence of these fruiting bodies is a reliable way to identify this disease.

There is no good economical method to control the disease. Some progress has been made in the discovery of resistant varieties, but none of the commercial varieties in Kansas can be recommended highly at this date.

TAKE-ALL

Take-all, also known as foot rot, straw blight, and white heads, is a worldwide disease of wheat and one of the many kinds of foot, crown, or root rots. Take-all varies greatly in

5. For more information see Ext. Circ. 216, Grain seed treatment in Kansas.

Fig. 12.—Speckled leaf blotch. Note the small black dots, the fruiting bodies of the parasite, in the killed areas.

severity from year to year due to weather and other factors. It is favored by cool, moist weather, and continuous cropping to susceptible crops. However, it is not caused by weather but by a parasitic soil-borne fungus.

Take-all has occurred in all parts of Kansas except the far western counties, i.e., Decatur to Meade and westward. The most damage has occurred in the central counties extending north and south from border to border. In this area losses as high as 95 percent in individual fields have been reported. Take-all has been known in Kansas for about 25 years. Preceding the drouth years the disease was prevalent and severe but it receded during the dry 1930's.

In infested fields take-all may occur on single plants surrounded by healthy plants, or it may occur on all of the plants in spots of various sizes and shapes (Fig. 13). Sometimes such spots may follow drill rows. In some fields small take-all spots may be found widely scattered, but in others they may be numerous and close together, in some cases joining together to form large areas, more or less circular and 1 or more rods across. A spot may be small at first and gradually increase in size as the season progresses.

The plants attacked by take-all at first become sickly yellow, finally wilt and become ashy gray and die. This may occur at any stage after growth is well started in the spring until the plants are mature. Accordingly, all degrees of stunting occur. If the plants have headed, the heads turn white, hence, the name "white heads." Kernels may be nearly normal or badly shriveled. Heads on plants that have been dead for some time turn black, particularly in rainy weather, due to the growth of various molds that tend to develop on sick or dead plants. This mold growth is entirely different from the fungi that cause take-all and smut. Plants killed by take-all usually pull up rather easily, because their roots have rotted. The more

Fig. 13.—Typical circular take-all spot in wheat field. The area shown above became diseased late enough so that white heads were formed.

advanced the disease, the easier the roots pull. Infected plants are easily lodged.

If the lower leaf sheaths surrounding the stems are removed from severely attacked plants, the bases will be found to be more or less blackened, either a solid black or speckled (Fig. 14). This black color is the most characteristic symptom on the plants attacked by take-all. No other foot rot produces it. The size of the black area increases in the more advanced stages of the disease. If the roots are washed free of soil, they too show a similar black color. When plants die just as the heads are beginning to fill, the stems may break over or buckle at the top joint. This buckling is different from that caused by the Hessian fly, which occurs much lower on the stem and just above the joints.

In general, take-all may be expected to get worse on infested land that is continuously cropped to wheat, but not always. Occasionally it will disappear under such conditions. Continuous wheat cropping of

Fig. 14.—Take-all infected plants at left showing blackened stems and rotted roots. Healthy plant is at right.

infested soil cannot be recommended, however, for if the disease does get worse, the loss may be as high at 95 percent of the crop. Under some conditions, a field may have only a trace of take-all year after year. On the other hand, take-all may show up in considerable abundance, apparently all in one year. When this happens, it means that traces of the disease have occurred unobserved in previous years.

Seed treatments do not help, since take-all is not seed borne. No known variety is resistant. Applying phosphorus helps, as do barnyard manures and green manure. The best procedure, however, is to change to nonsusceptible crops on infested land. The only susceptible crops are wheat, barley, and rye, and a number of wild grasses. A change for one year, using summer fallow or a nonsusceptible crop, helps but is not reliable. The best recommendation is to eliminate all susceptible crops from the land for three years before returning to wheat, which may be grown again successively not more than three years.

MINOR DISEASES

Black chaff. The bacterial disease known as black chaff ordinarily does not cause much damage to wheat in Kansas. However, in seasons of excessive moisture, black chaff is serious. For example, in 1951 it was the most destructive disease present, causing a loss of 6 percent. Development of this disease is favored by prolonged rainy periods. It spreads rapidly in thick stands, particularly in lodged fields. It attacks the leaves, stems, glumes and awns. Its most characteristic feature is brown to purple black blotches on the glumes and stems just below the head. Small narrow, elongate brown to black streaks develop on the glumes. The spots may coalesce and blacken the entire glume, giving a dark appearance to part or all of the head. Longer black streaks develop on the stems and may blacken a considerable portion of the stem. On the leaves narrow to irregular brown blotches, which often appear watersoaked, develop. The seed is shriveled in severe cases of the disease. The bacteria are carried on the seed and in diseased tissues and may remain alive for as long as two years. Crop rotation and use of mercury fungicides for seed treatment aid in control.

Basal glume rot or spikelet rot. This bacterial disease, like black chaff, is of little importance in Kansas except when prolonged rainy weather occurs at heading time. In the wet season of 1951, 2 percent of the wheat crop was destroyed. It often causes local damage to wheat on bottom land.

The disease makes its presence known by the blackened tip of the grain at the germ end. A light-brown rot develops at the base of the glumes and may extend into the base of the kernels. A sunken area forms where the rot is present

and a gray, slimy, exudate is usually discernible. Crop rotation will assist in controlling the disease.

Powdery mildew. This is a fungus disease which can do appreciable damage to wheat in Kansas in wet seasons, especially in low fields and lodged spots. Development of the disease is favored by cool, cloudy weather. If a heavy infection occurs during the period of tillering and stem elongation, the size of the kernels and yield of grain can be considerably reduced. Dense rank growth of wheat favors the development of the disease.

Mildew is most conspicuous on leaf blades but may also develop on leaf sheaths and floral bracts. Diseased parts become covered with a white or gray powdery mass of fungus tissue, often covering the entire blade. As the disease progresses the leaves turn yellow, then brown and gradually dry up. Late in the spring small fruiting bodies of the fungus may be found embedded in the gray fungus mats. No practical method of control is known.

Scab or head blight. This fungus disease frequently causes considerable damage when relative humidity and temperatures are high during heading and blossoming. Under such conditions, stands, yields, and quality of the wheat may be reduced. Infected spikelets first show a watersoaked appearance, then become yellow and finally a bleached-straw color. Usually a pink cast can be detected, especially at the base and in the crease of the kernel. The entire head often becomes infected. The infected kernels appear shriveled and scabby due to tufts of white to pink cottony outgrowths. The disease is often most evident when wheat is planted in a field following corn. Complete plowing under of stubble helps control it considerably. Crop rotation is the only practical means of control.

Glume blotch. This fungus disease is rarely important in Kansas. In occasional seasons severe shriveling of the kernels may occur in some fields. The disease occurs usually on the floral glumes and at the joints of the stems. Small elongate, narrow, sometimes rounded spots or lesions light to dark brown in color are formed. Small black dots or fruiting bodies often are present in these areas.

Crop rotation and field sanitation are important control measures. It also is important to plow under volunteer wheat in the summer.

Foliar eyespot. This is a fungus disease locally prevalent during wet seasons in eastern and central Kansas. It is primarily a disease of leaves. In early spring small oval to oblong, yellow spots develop, increase in size as the season progresses, and become light to dark brown with a yellowish zone at the margin giving the appearance of an "eye." Severely attacked leaves wither and die at the tips. Thor-

ough plowing under of the stubble helps control the disease. The best control is crop rotation.

Black point or kernel smudge. A seed disease of wheat frequently referred to as black point occurs in most grain growing areas and can cause considerable damage. It is characterized by a conspicuous brown or black discoloration of the kernel, particularly in the region of the embryo. The kernel does not become shrunken. Reduced seed value and usually reduced sales value of affected grain result. The development of black point is favored by periods of intermittent rain when the grain is maturing. During this period large numbers of airborne spores of the causal fungi are deposited on the developing kernels and infect the germ ends. No control measures are known.

NONPARASITIC DISEASES

Spring frost damage. Frost damage can well be included here, since it is a factor in reducing wheat yields in Kansas in certain years. Such damage generally occurs in the western half or two-thirds of the state, although it can occur in any area of the state when late spring frosts come at heading time. Frost damage may affect only the heads, resulting in sterility. If sterility is complete, the failure of the head to fill is the only distinguishing characteristic; if head sterility is only partial, there is a tendency for the remaining berries to overdevelop. Figure 15 shows head damage from late spring frosts, ranging from no damage through various aspects of partial head damage to complete sterility. At times there is also a whitish discoloration, designated

Fig. 15.—Illustrating spring frost damage in wheat heads. Left to right, no damage, bottom damage, top damage, center damage, top and bottom damage, and at extreme right all flowers destroyed, resulting in complete sterility.

blasting, of the whole or upper portion of the head.

Frequently the leaves are involved too, becoming discolored and dying. If stem damage occurs at this stage of plant development, it usually is confined to the first internode above the crown where damaged tissues become discolored. There is a tendency for this internode to split lengthwise, particularly under wind stress. This causes the culm to lodge.

Field observations and greenhouse studies have indicated that there is practically no difference among varieties in ability to withstand late spring frost injury. However, **early varieties are more likely to be damaged.** The critical factor is the stage of development, flowering being the most susceptible stage. Thus the development and use of early maturing varieties to escape drouth and certain diseases have increased the danger of injury from late spring frosts. Experimental work at Kansas State College has shown that at the time of pollination a temperature of approximately 27° F will kill the flower. Stages immediately prior to or following the flowering stage will withstand a degree or so lower temperature. Losses, while considerable in certain years, are difficult to estimate because of the variable severity and extent of the disorder. Losses are particularly difficult to estimate where only partial head sterility results because the remaining kernels develop larger than normal, and thus may compensate for the fewer number.

Physiologic leaf spot. It has been observed for years that certain varieties of winter wheat, particularly those related to Blackhull, develop a light green stippling in the

Fig. 16.—Physiologic spotting. First five leaves from left to right are flag leaves of Comanche, Pawnee, Turkey, BlueJacket, and Red-Chief varieties. The sixth is the first leaf below the flag leaf of Red-Chief, showing the coalescing of spots.

leaves as the plants approach heading. The size, number, and prominence of the spots vary with variety and season. In cases where the leaf area involved is relatively large, the situation is described as a spot, giving rise to the name leaf spot or physiologic leaf spot. The typical spot is yellowish in color, with a brown center (Fig. 16).

Turkey and Pawnee are relatively free of the condition, while moderate stippling occurs in Blackhull, Superhard, BlueJacket, MoKing, Kan-Queen, and Comanche. Severe stippling occurs in ChiefKan and Stafford, and may become very severe in RedChief and RedJacket. Even in RedChief and RedJacket the severity of the spotting varies from year to year. The spots on the leaves of these two varieties may coalesce and finally result in the leaves drying. This condition is not believed to reduce yields materially.

In all cases the situation is known to be physiologic in nature and definitely a heritable defect.

This bulletin has been written to provide descriptions of the important diseases of wheat that occur in Kansas. It is suggested that outbreaks of disease be reported immediately to the county agricultural agent. Working cooperatively with the county agent is the College Extension plant pathologist who visits each county periodically, conferring with the county agent, examining fields, and conducting demonstrations, particularly when new diseases or severe outbreaks of old diseases take place. The county agent may suggest that specimens be sent in to the Botany and Plant Pathology Department, Kansas State College, Manhattan, for examination. Where possible the complete plant should be sent and it should be kept moist but not wet.

It is hoped that the information provided in this bulletin will enable Kansas farmers to identify the various diseases in their wheat, and put into practice control measures that are recommended.

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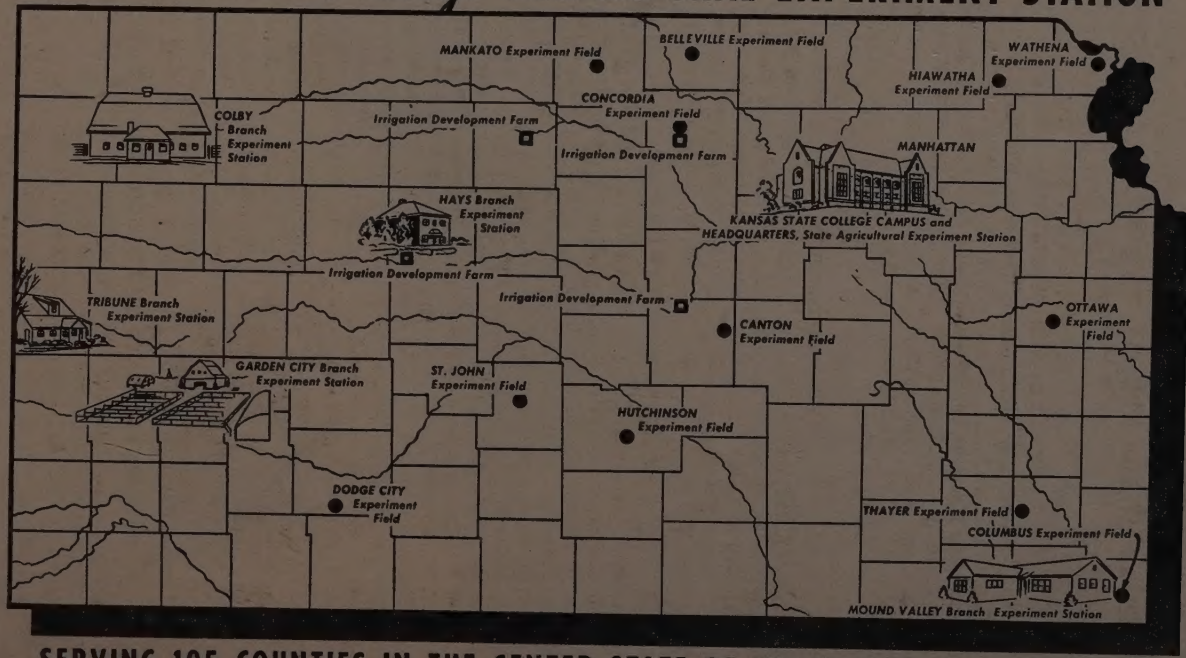

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